Accident Analysis and Prevention 151 (2021) 105914

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Tram, rail, bicycle: An unhappy triad? Rising incidence and resource consumption of tramline-associated bicycling accidents in Bern, Switzerland

Joël L. Gerber [a,b,*], Tobias Suppiger [a], Thomas C. Sauter [a], Michaela Traschitzger [a], Martin Müller [a,c,1], Aristomenis K. Exadaktylos [a,1]

[a] Department of Emergency Medicine, Inselspital, Bern University Hospital, Bern, Switzerland
[b] Department of General Surgery, Zofingen Hospital, Zofingen, Switzerland
[c] Institute of Health Economics and Clinical Epidemiology, Cologne University Hospital, Cologne, Germany

ARTICLE INFO

Keywords:
Bicycling
Tram
Costs
Injury pattern
Intoxication
Accident prevention

ABSTRACT

Bicycle traffic and the number of accidents have been increasing in Switzerland in recent years. However, little is known about specific types of bicycling accidents – such as tramline-associated bicycling accidents (TABA) – that are potentially avoidable.

This retrospective single center study of emergency department (ED) consultations analyzed TABA in the city of Bern, Switzerland. We analyzed the medical records of adult patients who presented to the ED after any bicycle accident. Patient and consultation characteristics were extracted. Incidence, important characteristics and ED resource consumption of TABA were compared with bicycle accidents that did not involve tramlines (BA). Furthermore, injury patterns and predictors of resource consumption were determined in TABA.

We included a total of 298 TABA and 2351 BA over the 5.6-year study period. TABA accounted for 11.2 % of all bicycling accidents. Descriptive analysis revealed a significant increase between 2013 (lowest) and 2016 (highest) of 33.0 % in the total number of BA and 132 % in the total number of TABA. Compared to BA, TABA patients were significantly older, more often female, had a less urgent triage, and less often needed resuscitation bay treatment, hospitalization or ICU-admission (all $p < 0.05$). In multivariable analysis, TABA were associated with greater needs for ED resources. Most TABA injuries were to limbs (70.5 %) or the head (53.0 %), including intracranial hemorrhage (2.3 %). The radiological work-up consumed most of the resources (37.5 %), followed by physicians' work (25.8 %). Statistically significant predictors of ED resource consumption in TABA were age, triage, resuscitation bay treatment, injuries to head/clavicle, and intoxication. One out of ten patients was intoxicated.

Although TABA is associated with less severe trauma than BA, it bears the risk of significant morbidity and high ED resource needs. Intoxications contribute to this problem. Our findings underline the need for preventive measures to reduce TABA in the future.

1. Introduction

It is estimated that over 2.5 million bicycles are ridden every day in Switzerland (Vereinigung der Schweizer Veloimporteure, 2017). Official Swiss registries have reported an upward trend in traffic accidents in recent years (Swiss Council for Accident Prevention, 2016). While bicycle accidents are generally underreported, a bicycle is involved in every fourth traffic accident (Shinar et al., 2018). Bicycle accidents that lead to consultation of an emergency department (ED) are of special public health interest, as they reflect the more severe crashes. Tramline-associated bicycling accidents (TABA) often share the same trauma mechanism, as the bicycle's wheel becomes stuck in the tramline while driving parallel to the tramlines (Teschke et al., 2016). This commonly happens when cycling at full speed and often results in severe

* Corresponding author at: Inselspital, Freiburgstrasse, CH-3010, Bern, Switzerland.
E-mail addresses: joel.gerber@insel.ch (J.L. Gerber), tobias.suppiger@luks.ch (T. Suppiger), thomas.sauter@insel.ch (T.C. Sauter), michaela.traschitzger@spitaltiefenau.ch (M. Traschitzger), martin.mueller2@insel.ch (M. Müller), aristomenis.exadaktylos@insel.ch (A.K. Exadaktylos).
[1] Shared last authorship.

https://doi.org/10.1016/j.aap.2020.105914
Received 8 March 2020; Received in revised form 17 November 2020; Accepted 21 November 2020
Available online 25 December 2020

trauma, which requires more resources in the ED (Swiss Council for Accident Prevention, 2016; Teschke et al., 2016).

Case series investigating TABA have been conducted in Scotland with 191 cases (Maempel et al., 2018), in Canada with 87 accidents (Teschke et al., 2016), in England with 41 accidents (Cameron et al., 2001), in the Netherlands with 10 casualties (Deunk et al., 2014), and in Switzerland with 5 patients (Papoutsi et al., 2014). These studies focused either on accidental mechanisms, injury patterns, or outcomes. Database analyses of bicycle crashes related to tramlines have been reported from Australia, with around 200 cases (11 % bicycling crashes of 1765 patients with tram-related traffic accidents), as well as a survey in Switzerland with 81 participants (Mitra et al., 2010; Hertach et al., 2018). Neither of these studies provided a subgroup analysis of accident mechanisms, injury patterns, resource consumption, nor outcomes. No study has yet addressed ED resource consumption.

A better understanding of sociodemographic distribution, trauma spectrum, and required ED resources would help us to insure the best medical practice through planning of resources and would encourage authorities to implement preventive strategies or public health campaigns.

Thus, this investigation has two study aims. Firstly, to describe and compare TABA with bicycling accidents without tramline involvement (BA) with respect to i) the total number and proportional incidence over the study period, ii) key patient and consultation characteristics, as well as iii) the ED resource consumption over the study period. Secondly, to perform an in-depth analysis of TABA and determine injury patterns as well as the detailed distribution and predictors of ED resource consumption.

2. Methods

2.1. Study design

This study was conducted at the Department of Emergency Medicine for Adults of the Inselspital, Bern University Hospital, Switzerland – a Level I trauma center with a catchment area of over 1.8 million people. This is a retrospective analysis of emergency consultations between 15th May 2012 and 1st December 2017 after bicycling accidents, with a special focus on TABA. The start of the study period was chosen to coincide with the introduction of the current computerized database (E-Care, ED 2.1.3.0, Turnhout, Belgium). All trauma patients in our department are treated according to the principles of Advanced Trauma Life Support (ATLS®).

2.2. Search strategy and eligibility criteria

All medical records of adult patients ($\geq$ 16 years) admitted to our ED within the given time period were screened using a defined search algorithm, consisting of multiple keywords coupled with the Boolean operator “OR”. Keywords consisted of 14 synonyms and short forms for bicycle (in German). The medical ED report of every hit in our computerized database was manually screened. Firstly, we included all patients presenting after a bicycle accident. These patient’s medical reports were then assessed for an association with tramlines in full text. All bicycle accidents were included, independently of the cause or the bicycle type.

Exclusion criteria were patients <16 years, as they are not routinely treated in our ED for adults, and consultations with incomplete medical records or administrative data, such as missing resources.

2.3. Data collection and extraction

For all bicycle accidents the following data were extracted from the hospital database: i) sociodemographic data (age, sex, private insurance, nationality) and ii) data reflecting urgency of the consultation, i.e. triage level according to the Swiss emergency triage scale (Rutschmann et al., 2018), and special ED treatment in the resuscitation room, as well as iii) the work performed and material consumed, as documented by procedural codes (so called tax codes, see below) by every health professional for billing purposes. Quality of documentation and coding is assured by periodic training of all health professionals and is independently rechecked by specifically trained persons within the department in each case. Lastly, administrative/procedural data such as entry date in the ED, hospitalization and intensive-care unit (ICU) admission, and in-hospital death were extracted for all bicycle accidents.

For the in-depth-analysis of TABA, the comprehensive medical report, created routinely by the attending physician, was extracted and analyzed in full text. The medical ED report includes diagnoses, history, diagnostic measures, and discharge procedure. Intoxication was assigned according to the medical report, if the attending physician diagnosed alcohol or drug intoxication irrespective of further diagnostic testing. Data on injury patterns were manually extracted into a predefined, anonymized data table.

2.4. ED resource consumption

To study ED resource consumption and identify predictors of resource consumption, the total ED resource consumption was determined. This reflects the total ED costs of each patient.

In Switzerland, each performed ED procedure is coded with a different procedural code taken from the Swiss medical tariff system *Tarmed* (Swiss Confederation, 2018). For each code, a number that reflects the complexity and costs of the procedure is assigned. The number is measured in tax points; one tax point is about 0.86 Swiss Francs in the canton of Bern. However, it can vary, depending on the canton and the hospital. The codes used at our ED were grouped into five categories: physician, nurse, laboratory, radiology, and other (e.g. material resources). The sum of the five categories was defined as the total ED resource consumption of a consultation. All procedural codes of a consultation were extracted from the administrative database by a medical controller of our ED (OpenText Suite for SAP® Solutions, OpenText Corporation, Waterloo, Canada).

2.5. Statistical analysis

All statistical analyses were performed using the statistical program Stata® 13.1 (StataCorp LLC, College Station, Texas, USA).

In all descriptive analysis, such as the presentation of the distribution of sociodemographic parameters, urgency, injury pattern, and procedural variables, categorical variables are shown in absolute numbers accompanied by per cent in each category. The distribution of continuous variables is described by the median and interquartile range (IQR).

To address the primary aim of the study, several different analyses were performed to compare TABA and BA. The total number as well as the proportional incidence per 1000 ED consultations were calculated and presented over the study period in each year for TABA and BA separately. The value of the slopes including 95 % CI of the trend line of the yearly total number or the proportional incidence over the study period for the two different types of bicycling accident and was determined using univariable linear regression analysis.

To compare sociodemographic, urgency, procedural variables as well as ED resource consumption and its distribution in subgroups between TABA and BA, Chi-square and Wilcoxon rank sum tests were used, as appropriate.

The median ED resource consumption per case in each year of the study period was presented separately for the two bicycling accident groups and slopes. The 95 % CI of the trend lines were calculated using univariable linear regression analysis.

Lastly, the total ED resource consumption was compared for the two different types of bicycling accidents, using unadjusted (univariable linear regression analysis) and multivariable linear regression analysis. All variables with identified significant associations ($p < 0.05$) with the

type of bicycle accidents were included as covariables in the multivariable linear regression model.

The second study aim, the in-depth analysis of TABA, incorporated several objectives. Firstly, the injury patterns and consultation characteristics were presented using descriptive statistics. Secondly, a pie chart was drawn to display the distribution analysis of the total ED resource consumption in the different resource subgroups. Thirdly, associations between injury patterns and consultation characteristics with the total ED resource consumption were determined using univariable linear regression analysis. Identified significant ($p < 0.05$) predictors were used to build a multivariable model. To obtain the final model to predict the total ED resource consumption in TABA, a multivariable linear regression model was built using a stepwise forward selection regression (criteria for inclusion: $p < 0.05$). Backward selection regression was used for sensitivity analysis.

In all regression analysis with the outcome of total ED resource consumption, resource consumption was ln-transformed to account for the non-normal distribution of the total ED resource consumption. The obtained coefficients were then expressed as exponentials as they correspond to the geometric mean ratio (GMR) of the non-log transformed values (Feng et al., 2013). The GMR for each predictor was presented together with the 95 % confidence interval (CI). $p < 0.05$ was considered significant. No adjustment for multiple testing was performed in this exploratory analysis.

2.6. Ethical considerations

The study was classified as a quality evaluation study by the Ethics Committee of the Canton of Bern, Switzerland, and informed consent was waived (KEK-2018−00198).

3. Results

Out of the 220,355 emergency consultations over the study period of 5.6 years, the database query yielded 5850 hits. Primary screening of those hits revealed 2676 medical records of patients presenting after a bicycle accident. Secondary screening of these records established that 301 accidents were associated with tramlines and 2375 were not. Three of the consultations in the TABA group (1.0 %) and 20 of the consultations in the BA group (0.8 %) were excluded due to incomplete medical records or administrative data. Additionally, four patients in the BA group (0.2 %) were excluded due to age (<16 years). Thus, 2649 bicycle accidents were included for the comparison of TABA and BA. Furthermore, 298 TABA consultations were included in the in-depth-analysis of injury patterns and predictors of ED resource consumption. Fig. 1 shows the flowchart of the study.

3.1. Comparison of bicycle accidents with and without tramline involvement

3.1.1. Total number and proportional incidence

In total, 11.2 % of all bicycling accidents were assigned to TABA.

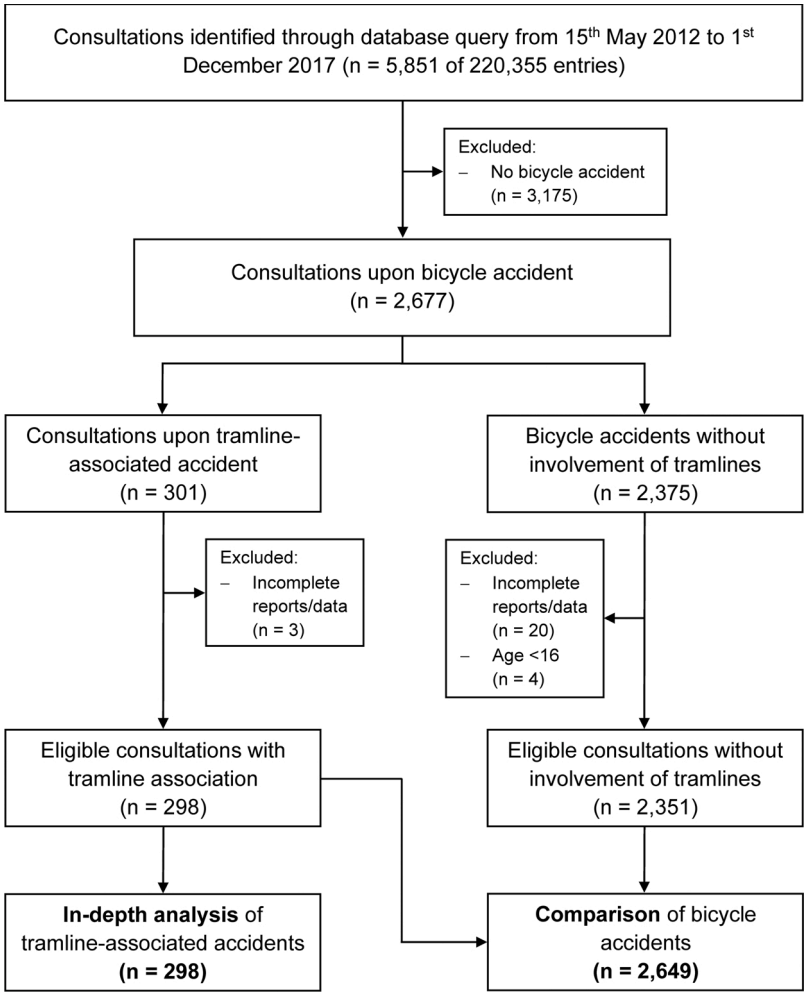

Fig. 1. Study flow chart.

Over the study period, 217,979 consultations of adult (≥16 years) patients were registered. The proportional incidence was then 1.4 per 1000 ED consultations for TABA and 10.8 per 1000 ED consultations for BA.

The total number of BA and TABA was lowest in 2013 - with 364 and 34 accidents. The number of BA was greatest in 2017 of BA with 484 – as estimated from the 11 months observation period in 2017. The number of TABA was greatest in 2016, with 79 accidents. Between 2013 and 2016, this corresponds to an increase of 33 % in the total number of BA and of 132 % in the numbers of TABA.

The trend lines of the total number of accidents showed significant positive slopes, with an absolute increase of 7.7 accidents every six months (95 % CI: 0.7, 14.7, p = 0.035) of BA and 2.4 (95 %: 0.7, 4.1, p = 0.012) of TABA (Fig. 2A).

The proportional incidence of TABA and BA fluctuated over the study period, although the incidence of TABA and BA increased over time (Fig. 2B). The trend line for TABA showed a significant increase over the study period, with an increase of approximately 0.1 TABA per 1000 ED consultations every six months (slope of the trend line: 0.09, 95 % CI: 0.01, 0.19, p = 0.043), while no significant time effect was found in BA (slope: 0.20, 95 % CI: -0.25, 0.65, p = 0.340). The proportional incidence of TABA was lowest in 2013, with 0.9 per 1000 ED consultations and highest in 2016, with 1.8 per 1000 ED consultations.

3.1.2. Patient and consultation characteristics

The overall median patient age of all bicycling accidents was 37 years (IQR: 28−52) with 64.8 % males. More than two third of the patients (76.7 %) were Swiss and 11.4 % had a private insurance, which is comparable to the distribution of the population. Resuscitation bay treatment was performed in 24.3 % of all accidents. Hospitalization or ICU admission was needed in 31.0 % or 13.5 % of cases, respectively. 18 patients (0.7 %) died during the hospital stay (Table 1). Patients with TABA were significantly older, were less often male and less often privately insured compared to BA. The presentation of life-threatening and high urgency triage categories as well as resuscitation bay treatment was significantly more often found in BA than TABA. In line with this, the hospitalization and ICU admission rate (p < 0.001 and p = 0.001, respectively) were significantly higher in BA (33.3 % and 14.3 %, respectively) than in TABA (13.4 % and 7%, respectively). All 18 in-hospital deaths were registered in the BA group (p = 0.130).

3.1.3. ED resource consumption

In descriptive analysis, distributions of total ED resource consumption in the two subgroups were similar (Fig. 3A). The mean percent of physician resources of the total ED resource consumption was slightly higher in TABA (51.6 % vs. 46.5 %, p < 0.001), the laboratory expenses slightly lower in TABA than BA (4.5 % vs. 7.4 %, p < 0.001). Radiologic resources accounted for 36.2 % and 38.2 %, respectively (TABA vs. BA, p = 0.165).

The median total ED resource consumption per case was 877 tax points (IQR 807−1,016) in BA and 723 tax points (95 % CI: 701, 800) in TABA. The median ED resource consumption per case increased similarly over the study period in TABA and BA (Fig. 3B). The slopes of the linear fits of the median ED resource consumption per case over the study period (see Fig. 3B) were slightly smaller in BA with +33 tax points (95 % CI: 15, 51, p = 0.002) more per half year than in TABA with +52 tax points (95 % CI: -2, 132, p = 0.173), but the 95 % CI overlapped.

In univariable linear regression analysis, there was no significant association between the type of accident and ED resource consumption (TABA vs. BA, GMR: 0.91, 95 % CI: 0.79, 1.05, p = 0.200). After adjustment for the significant sociodemographic and urgency characteristics (found in Table 1), multivariable linear regression was used to predict total ED resource consumption (ln-transformed). The geometric mean of total ED resource consumption of TABA was 1.13 (95 % CI: 1.01, 1.27, p = 0.032) times higher than the geometric mean of total ED resource consumption in BA.

3.2. In-depth-analysis of TABA

3.2.1. Injury patterns

Extremity trauma including wounds (25.8 %), contusions (45.4 %), and fractures (18.1 %) were most often reported (70.5 %). Head injury

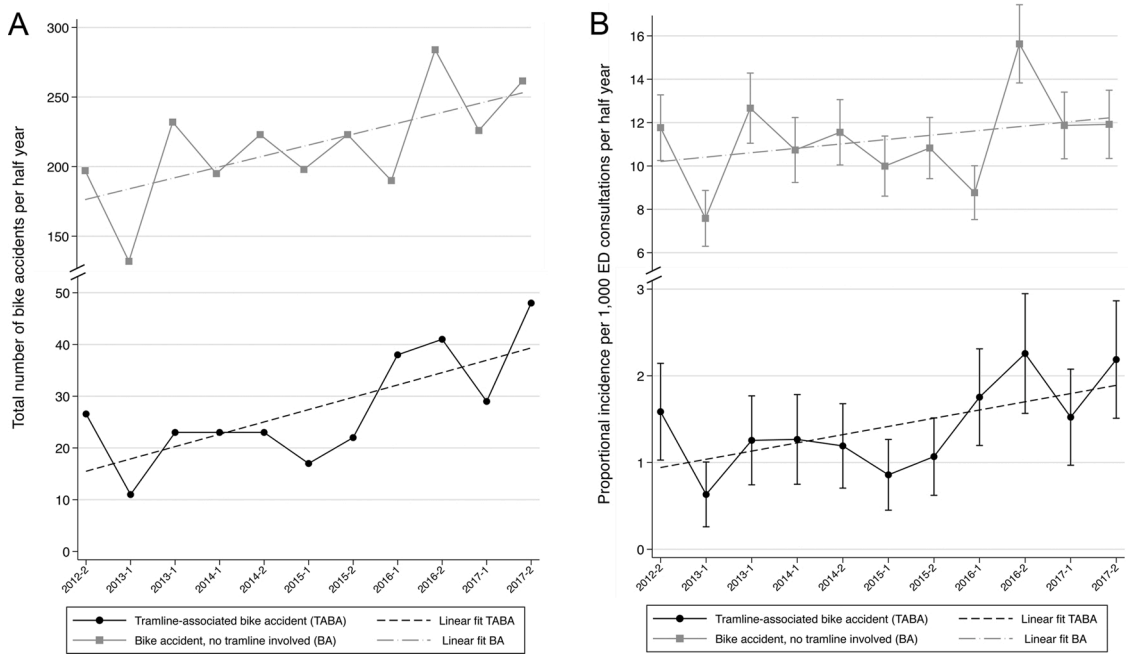

Fig. 2. A) Total number of bicycle accidents per half year with linear fits (dashed line) in TABA (black) and BA (grey). The total numbers for the second half of 2012 and 2017 were calculated based on the totals observed in 8 months in 2012 and 5 months in 2017. B) Mean proportional incidence with 95 % CI of TABA and BA per 1000 ED consultations per half year over the study period; dashed lines are linear fits, 2012-2 refers to the numbers from May to December 2012 and 2017-2 from July to December 2017.

Abbreviations: BA, bicycle accidents without tramline involvement; ED, emergency department; TABA, tramline-associated bicycle accidents.

Table 1
Patient and consultation characteristics. Tramline-associated bicycle accidents (TABA) compared to bicycle accidents without tramline association (BA).

	TABA (n = 298)		BA (n = 2351)		Total (n = 2649)		p
Sociodemographic variables							
Age, years [median (IQR)]	43	(27–45)	38	(28–54)	37	(28–52)	0.001
Sex, [n (%)]							
Female	139	(46.6)	793	(33.7)	932	(35.2)	
Male	159	(53.4)	1558	(66.3)	1717	(64.8)	<0.001
Private insurance, [n (%)]	22	(7.4)	279	(11.9)	301	(11.4)	0.022
Swiss, [n (%)]	216	(72.5)	1817	(77.3)	2033	(76.7)	0.064
Urgency							
Resuscitation bay, [n (%)]	41	(13.8)	602	(25.6)	643	(24.3)	<0.001
Triage, [n (%)]*							
Life-threating	10	(3.4)	253	(11.0)	263	(10.1)	
High urgency	71	(23.8)	638	(27.7)	709	(27.3)	
Urgency	202	(67.8)	1283	(55.7)	1485	(57.1)	
Non-urgency	15	(5.0)	128	(5.6)	143	(5.5)	<0.001
Procedure							
ICU admission, [n (%)]	21	(7.0)	337	(14.3)	358	(13.5)	0.001
Hospitalization, [n (%)]	40	(13.4)	782	(33.3)	822	(31.0)	<0.001
In-hospital death, [n (%)]	0	(0.0)	18	(0.8)	18	(0.7)	0.130

Abbreviations: BA, bicycle accidents without a tramline association; ICU, intensive care unit; IQR, interquartile range; TABA, tramline-associated bicycle accidents.
* The triage category was missing in n = 49 (2.1 %) of BA.

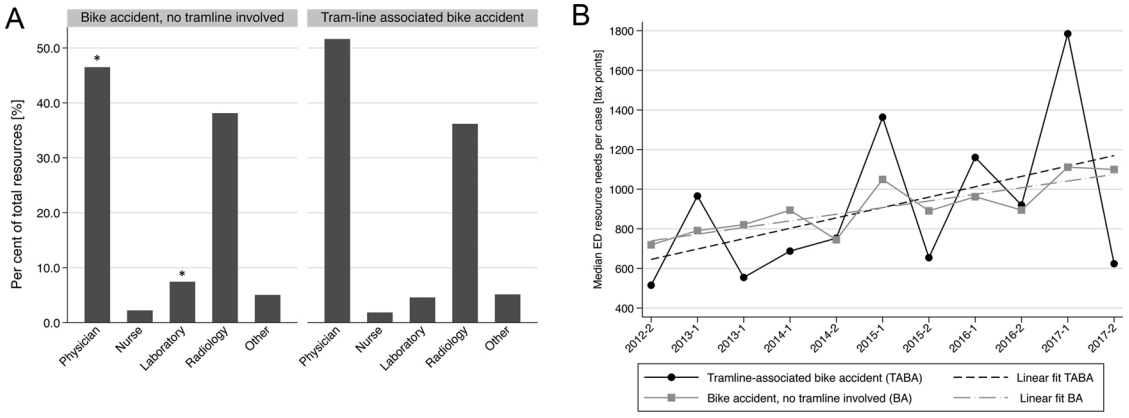

Fig. 3. A) Distribution of the total resource consumption in the different resource subgroups according to type of bicycle accident. B) Changes in the median ED resource consumption per case and half year over the study period in TABA and BA, 2012-2 included the accidents from May and December 2012, 2017-2 included the accidents from July to December 2017; dashed lines are linear fits.
Abbreviations: BA, bicycle accidents without tramline involvement; ED, emergency department; TABA, tramline-associated bicycle accidents. * significant group difference ($p < 0.05$)

and facial trauma was documented in 53 % of the consultations. Non-severe traumatic brain injury and wounds in the face/head were reported in 31.2 % and 33.6 %, respectively. Intracranial bleeds were found in 2.3 % of the patients. Chest trauma (12.8 %), including fractures of the clavicle (5.0 %) and pneumothorax (1.0 %) as well as abdominal trauma (2.0 %) including organ laceration (0.2 %) were less common. An intoxication was reported in 9.7 % of the analyzed 298 TABA. The full list of the distribution of injury patterns and contextual characteristics is shown in Appendix A.

3.2.2. Distribution of resource consumption

The detailed distribution of the total resource consumption of TABA in the different resource subgroups is shown in Fig. 4. The radiological work-up consumed most of the invested ED resources (37.5 %), followed by physicians' costs (25.8 %), and laboratory expenses (20.4 %). Computed tomography (CT) scans contributed to more than half (50.4 %) of the radiology resources. Administrative tasks accounted for 58.2 % of physicians' resources. In consultations with greater consumption of ED resources, there was a shift from physicians' effort to more radiological expenses.

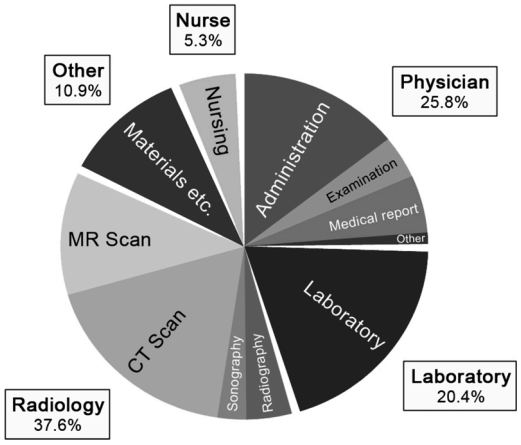

Fig. 4. Distribution of total resource consumption in TABA.
Abbreviations: CT, computed tomography; MR, magnetic resonance.

3.2.3. Predictors of total ED resource consumption

3.2.3.1. Univariable linear regression analysis. Predictors of resource consumption were identified through univariable analysis and are presented in Table 2. Thoracic and abdominal trauma, including lumbar spine and pelvic fractures, showed the strongest association with total ED resource consumption. Traumatic brain injury with loss of consciousness in history and reduced Glasgow Coma Scale (GCS) score likewise showed a noticeable positive association, particularly if intracranial bleeding or a skull fracture was present. Furthermore, documented intoxication (mixed causes) was associated with total ED resource consumption. Higher triage category and especially initial treatment in the resuscitation bay were strong predictors of total ED resource consumption.

Table 2
Predictors of total ED resource consumption in tramline-associated bicycle accidents (n = 298) as identified by univariable linear regression analysis. If not further specified, the baseline category for the variable is "not present".

Total ED resources (ln-transformed)	GMR	95 % CI	p
Sociodemographic variables			
Age, [per year older]	1.02	(1.01, 1.03)	<0.001
Sex			
Female	1.00	(Baseline)	
Male	1.14	(0.91, 1.44)	0.251
Private insurance	0.89	(0.57, 1.38)	0.596
Nationality			
Other nationality than Swiss	1.00	(Baseline)	
Swiss	1.19	(0.92, 1.54)	0.187
History			
Loss of consciousness	2.68	(1.62, 4.42)	<0.001
Documented intoxication	1.78	(1.21, 2.62)	0.003
Urgency			
Special ED treatment			
No	1.00	(Baseline)	
Resuscitation bay	4.07	(3.03, 5.46)	<0.001
Triage, [less category urgent]	0.49	(0.41, 0.58)	<0.001
GCS on arrival, [per point more]	0.38	(0.21, 0.69)	0.002
Head injury/Facial trauma	1.76	(1.41, 2.2)	<0.001
Traumatic brain injury, with bleeding	3.82	(1.81, 8.07)	<0.001
Traumatic brain injury, without bleeding	1.82	(1.43, 2.31)	<0.001
Whiplash injury	1.32	(0.71, 2.43)	0.379
Wound head and face	1.34	(1.05, 1.71)	0.017
Neurocranial fracture	3.71	(1.65, 8.34)	0.002
Facial skull fracture	1.77	(1.12, 2.80)	0.014
Cervical spine fracture	–	–	–
Thoracic trauma	1.29	(0.91, 1.82)	0.147
Clavicle fracture	2.20	(1.31, 3.71)	0.003
Scapula fracture	1.17	(0.28, 4.82)	0.828
Rib fracture	1.23	(0.45, 3.36)	0.687
Thorax spine fracture	1.3	(0.18, 9.64)	0.794
Thorax contusion	1.08	(0.64, 1.84)	0.767
Pneumothorax	4.70	(1.49, 14.77)	0.008
Abdominal trauma	2.07	(0.91, 4.7)	0.081
Spleen laceration	4.68	(0.64, 34.3)	0.129
Renal laceration	1.02	(0.14, 7.57)	0.981
Lumbar spine fracture	5.95	(0.81, 43.5)	0.079
Pelvis fracture	3.07	(1.13, 8.31)	0.028
Extremity trauma	0.68	(0.53, 0.87)	0.003
Contusion extremities	0.76	(0.60, 0.95)	0.017
Luxation joint	1.33	(0.78, 2.26)	0.287
Nerve vessel injury	1.53	(0.72, 3.29)	0.269
Wound extremities	0.92	(0.71, 1.20)	0.546
Femur fracture	1.93	(0.79, 4.73)	0.151
Tibia fracture	1.30	(0.18, 9.58)	0.799
Humerus fracture	1.62	(0.88, 2.99)	0.120
Ulna fracture	0.79	(0.32, 1.94)	0.601
Radius fracture	0.73	(0.45, 1.18)	0.196
Hand fracture	0.75	(0.44, 1.30)	0.310
Procedure			
Emergency operation	1.51	(1.10, 2.06)	0.011
Hospitalization	2.42	(1.75, 3.35)	<0.001
ICU admission	1.76	(1.12, 2.75)	0.014

Abbreviations: CI, confidence interval; ED, emergency department; GCS, Glasgow Coma Scale; GMR, geometric mean ratio; ICU, intensive care unit.

3.2.3.2. Multivariable linear regression analysis. Table 3 shows the independent predictors identified through multivariable linear regression analysis to predict the total ED resource consumption – using a stepwise forward selection model ($p < 0.05$) – and including all sociodemographic, anamnestic/context, urgency, and trauma variables that showed a significant association in the univariable linear regression analysis (compare Table 2). Resuscitation bay treatment increased the geometric mean of the total ED resources by the factor of 2.75 (95 % CI: 2.00, 3.77, <0.001), while an increase of from one triage category to the next (less urgent triage) decreased the geometric mean by the factor of 0.78 (95 % CI: 0.65, 0.95, $p = 0.012$). Furthermore, clinical characteristics such as skull fracture, loss of consciousness, clavicle fracture, brain injury without bleeding, and alcohol or drug intoxication increased the geometric mean of the total ED resource consumption by between 35 % (brain injury without bleeding) and 109 % (skull fracture). For instance, for the presence of documented intoxication, a GMR of 1.58 (95 % CI: 1.15, 2.16, $p = 0.005$) was found compared to consultations without a documented intoxication.

4. Discussion

This retrospective study aimed to analyze emergency consultations after bicycle accidents associated with tramlines in the city of Bern, Switzerland – with a special emphasis on resource consumption. We furthermore determined incidence over time, injury patterns, and predictors of ED resource consumption. Incidence, patient and consultation characteristics, and total resource consumption were compared with all bicycling accidents without involvement of tramlines over the study period. There was a significant increase in the total number of both types of bicycle accidents over the study period.

Presentation with life-threatening injuries, resuscitation bay treatment and high urgency triage was significantly more frequent in the BA group. However, consultations in the TABA group demanded significantly more resources compared with the BA group, if adjusted for patient characteristics, triage category and resuscitation bay treatment. Injury of the head and torso as well as acute intoxication in general (causes not differentiated) led to significantly higher demand on resources, which then was predominantly spent in radiological work-up.

4.1. Incidence and severity

Several studies have reported a recent increase in the incidence of bicycling accidents as well as crashes with severe injuries in general, and specifically for e-bikes, as their popularity increases (Mitra et al., 2010;

Table 3
Predictors of total ED resource consumption in tramline-associated bicycle accidents (n = 298) as identified by multivariable linear regression analysis (stepwise forward selection, $p < 0.05$). If not further specified, the baseline category for all variables is "not present".

Total ED resources (ln-transformed)	GMR	95 % CI	p
Special ED treatment			
No	1.00	(baseline)	
Resuscitation bay	2.75	(2.00, 3.77)	<0.001
Skull fracture	2.09	(1.07, 4.07)	0.031
Loss of consciousness	1.58	(1.03, 2.43)	0.037
Clavicle fracture	1.77	(1.15, 2.71)	0.010
Documented intoxication	1.58	(1.15, 2.16)	0.005
Brain injury without bleeding	1.35	(1.09, 1.67)	0.006
Age, [per year increase]	1.01	(1.00, 1.02)	0.003
Triage, [less urgent]	0.78	(0.65, 0.95)	0.012

Abbreviation: CI, confidence interval; ED, emergency department; GMR, geometric mean ratio.
*The same model was obtained using stepwise backward selection linear regression.

Sanford et al., 2015; Hertach et al., 2018). One group furthermore identified on-road tram rails as a statistically significant risk factor for the incidence of bicycling accidents (Vandenbulcke et al., 2014). Two typical mechanisms of accidents related to tramways have been suggested in pertinent literature: Wedging of bicycle wheels in (on-road) tram rails and skidding of bicycle wheels on the tram rails (Deunk et al., 2014; Teschke et al., 2016; Hertach et al., 2018). In our data, more than one of ten bicycling accidents was related to a tramline and many patients presented with severe injuries in either group, which underlines the importance of TABA. In accordance with pertinent literature, the number of accidents seemed to be rising continuously and significantly in both groups, although we found no significant changes in the total number or proportional incidence of TABA or of BA. On one hand, this may be a result of increasing road traffic in Switzerland (Swiss Confederation, 2019a), but on the other hand it might also be due to an increase in bicycle traffic (Swiss Council for Accident Prevention, 2016), because of the increasing popularity of e-bikes – with a recent rise in severe accidents (Swiss Confederation, 2019b) –, and owing to the high number of intoxications.

However, triage category and resuscitation bay treatment were more frequent in the BA group than in the TABA group. Accordingly, hospitalization, ICU admission and mortality rates were higher in the BA group. It has previously been reported in different countries that a substantial proportion of patients after bicycling accidents in general present with minor trauma (Aertsens et al., 2010; Palmer et al., 2014). While only slightly more male patients seemed involved in major bicycle accidents, it was reported that significantly more females suffered minor bicycle accidents (Palmer et al., 2014). Against this background, one reason for the discrepancy in the injury severity in our study might be the significantly higher rate of male versus female patients (2:1) in the BA group, whereas gender distribution in the TABA group just reflected the general population. Another explanation could be that patients with (presumably) severe injuries and therefore high ED resource consumption are triaged to our ED, which is a tertiary trauma center with a considerable catchment area. While severe BA that occur at some distance are triaged to our ED, distant BA with minor injuries are assumed to present near to home. However, as TABA occur only in major cities with tramlines, the latter patients may mainly present in the same district. Otherwise, bicycle accidents with major injuries could also occur more frequently without involvement of tramlines. Since a systematic reporting of bicycling accidents is missing in Switzerland, we cannot draw a conclusive statement in that regard with the available data.

4.2. Trauma spectrum, predictors of resource consumption, and prevention

This is the first study to assess the ED resource consumption of bicycle accidents related to tramlines. Injuries of the extremities and the head were predominant, which corresponds to injury patterns of similar case series (Cameron et al., 2001; Teschke et al., 2016; Maempel et al., 2018). It is not surprising that trauma to the head was determinant for high resource consumption. It must be noted here that helmet use is only mandatory for motorized bicycles in Switzerland (Confederation, 2019). On the other hand, it does not appear evident why clavicle fractures were predictive of high costs to the same extent, as for instance loss of consciousness. Although this injury is typical for bicycle accidents, it might have caused broader radiological work-up, since concomitant thoracic injury appears to be common (van Laarhoven et al., 2019). Remarkably, intoxications were a statistically significant risk factor for high ED resource consumption. One in 10 patients in our study was intoxicated. Similar intoxication rates have been described in pertinent literature and seen as a major concurrent cause of bicycling accidents (Papoutsi et al., 2014; Teschke et al., 2016; Airaksinen et al., 2018). Airaksinen et al. found a lower frequency of helmet use and consequently higher rate of head injuries for accidents with intoxicated cyclists in general (Airaksinen et al., 2018). In the latter study, which appears to be the only one to examine treatment costs, one third of the patients were intoxicated. Surprisingly, in contrast to our results, the mean cost of treatment was lower for intoxicated patients (Airaksinen et al., 2018). Aside from the fact that our investigation focused on tram-related accidents, 40 % of the accident victims in the sober group were children, whereby we excluded infants. It may be important that the recruitment period of this study was ten years before our study and it was not reported whether patients were treated according to the ATLS® principles. It is therefore difficult to compare these results.

Resource consumption was higher in the BA group. Change in resource consumption over time was comparable in the two groups. The discrepancy in absolute ED resource consumption can be explained by more frequent presentation with life-threatening injuries, higher resuscitation bay treatment rate and high urgency triage rate in the BA group. After adjustment for patient characteristics, triage category and resuscitation bay treatment, consultations in the TABA group demanded significantly more resources than with the BA group in multivariable linear regression analysis. The reason for this remains unclear. Higher resource consumption within the TABA group was mainly caused by radiological work-up. In fact, when resource consumption was higher, expenses shifted from medical consultation (physician's effort) to medical imaging. Intoxication, for instance, might lower the physician's threshold for CT scan due to impaired vigilance, which consequently leads to a relevant increase in treatment costs in favor of a conclusive injury assessment.

Problem-centered prevention measures could incorporate consistent helmet use and address the issue of intoxicated bicycling, as these seem to be relevant risk factors for severe injuries and high costs. Other suggested preventive strategies include i) increasing individual knowledge by education of all traffic participants, particularly raising the awareness of cyclists, ii) the use of larger bicycle tires, and iii) modifications in route design such as separation of tramline and bicycle ways, rail inserts and protected intersections (Castanier et al., 2012; Deunk et al., 2014; Naznin et al., 2016; Teschke et al., 2016). Cycle-friendly tram rails, for instance, are being evaluated in Switzerland (Baumann, 2019; Schweizer Radio und Fernsehen SRF, 2019). In view of our findings, we consider that accidents related to on-road tramlines are a public health issue, particularly since specific causes of many of these accidents (i.e. wedging or skidding) seem easy to address and many of these accidents may be preventable. Special emphasis in prevention should be laid on the prevention of intoxicated bicycling, and consistent helmet use in tandem with larger built environment changes that would prevent bicyclist interactions with tramlines in the first place wherever possible.

4.3. Limitations and strengths

To our knowledge, the present study is the largest investigation of bicycle accidents related to tramlines that has been performed and the first to address resource consumption. It has, however, limitations that merit discussion. This is a single center study that exclusively investigates the situation in the city of Bern and patients who presented to our ED, which limits external validity. Undetected false or incomplete reporting (medical reports) and coding (administrative data) may have occurred due to the retrospective design. The estimated number of unreported cases is unclear. Since the Inselspital is the only university hospital and tertiary trauma center in the wider area, patients with (presumably) severe injuries and consequently high ED resource consumption are more likely to be triaged to our trauma center. However, there are six other ED in the city of Bern which patients may consult, particularly after minor traumata. Moreover, we do not know the number of cases with consultations to the general practitioner or without any medial consultation after tramline-associated bicycling accidents. Since systematic reporting of such accidents is lacking, we could not extract data such as the incidence of e-bike accidents or the rate of helmet use.

4.4. Unanswered questions and future research

Tramline-associated bicycle accidents should be consistently registered and systematically analyzed by authorities and research workers. Preventive measures must be tested. All measures should be continuously monitored, reevaluated and adapted.

5. Conclusions

The incidence and ED resource consumption of tramline-associated bicycling accidents in Bern, Switzerland, seem to be rising. Many of these seem to be related to intoxications. Head injuries are frequent and lead to higher resource needs. Thus, we can conclude that tram, rail, bicycle, and intoxication are an unhappy tetrad.

As the incidence is expected to increase further and many patients present with severe injuries, we consider this is a public health issue. Data indicate that a substantial part of tramline-associated bicycling accidents might be effectively addressed and avoided through preventive measures. Authorities must recognize this issue and establish preventive measures.

Author statement

All information presented in this manuscript has not yet been published and the manuscript is not under consideration elsewhere. All authors have made substantial contributions to the conception and design of the study, have critically re-revised the manuscript for important intellectual content and have approved the revised version.

Consent for publication

All authors have approved the final manuscript.

Availability of data and material

The data are available on request.

Authors' contributions

MM and AKE conceived the study and designed the trial. TS screened the database and extracted the data. MM and AKE supervised the conduct of the trial and data collection. MM analyzed and visualized the data. JLG and MM drafted the manuscript. TS, TCS, MT and AKE revised the manuscript for important intellectual content. All authors read the final draft.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. MM was funded by a personal grant from the Swiss Academy of Medical Sciences, Bern, Switzerland.

Declaration of Competing Interest

The authors report no declarations of interest.

Acknowledgement

Not applicable.

Appendix A

	Total (n, %)	
Anamnestic/context		
Loss of consciousness, [n (%)]	16	(5.4)
Documented intoxication, [n (%)]	29	(9.7)
GCS on arrival, [n (%)]		
13	1	(0.3)
14	7	(2.3)
15	290	(97.3)
Head injury/Facial trauma, [n (%)]	158	(53.0)
TBI, with intracranial bleeding, [n (%)]	7	(2.3)
TBI, without intracranial bleeding, [n (%)]	93	(31.2)
Whiplash injury, [n (%)]	11	(3.7)
Wound head and face, [n (%)]	100	(33.6)
Dental injury, [n (%)]	22	(7.4)
Neurocranial fracture, [n (%)]	6	(2.0)
Facial skull fracture, [n (%)]	20	(6.7)
Chest trauma, [n (%)]	38	(12.8)
Clavicle fracture, [n (%)]	15	(5.0)
Scapula fracture, [n (%)]	2	(0.7)
Rib fracture, [n (%)]	4	(1.3)
Thoracic spine fracture, [n (%)]	1	(0.3)
Thorax contusion, [n (%)]	15	(5.0)
Pneumothorax, [n (%)]	3	(1.0)
Abdominal trauma, [n (%)]	6	(2.0)
Liver laceration, [n (%)]	0	(0.0)
Spleen laceration, [n (%)]	1	(0.3)
Renal laceration, [n (%)]	1	(0.3)
Lumbar spine fracture, [n (%)]	1	(0.3)
Pelvis fracture, [n (%)]	4	(1.3)
Extremity trauma, [n (%)]	210	(70.5)
Contusion extremities, [n (%)]	135	(45.3)
Articular luxation, [n (%)]	15	(5.0)
Nerve vessel injury, [n (%)]	7	(2.3)
Wound extremities, [n (%)]	77	(25.8)

(*continued on next page*)

(*continued*)

Femur fracture, [n (%)]	5	(1.7)
Tibia fracture, [n (%)]	1	(0.3)
Fibula fracture, [n (%)]	0	(0.0)
Foot fracture, [n (%)]	0	(0.0)
Humerus fracture, [n (%)]	11	(3.7)
Ulna fracture, [n (%)]	5	(1.7)
Radius fracture, [n (%)]	18	(6.0)
Hand fracture, [n (%)]	14	(4.7)

Contextual characteristics and injury patterns of tramline-associated bicycle accidents (n = 298).
Abbreviations: GCS, Glasgow Coma Scale; TBI, traumatic brain injury.

References

Aertsens, J., De Geus, B., Vandenbulcke, G., Degraeuwe, B., Broekx, S., De Nocker, L., Liekens, I., Mayeres, I., Meeusen, R., Thomas, I., Torfs, R., Willems, H., Int Panis, L., 2010. Commuting by bike in belgium, the costs of minor accidents. Accid. Anal. Prev. 42 (6), 2149–2157.

Airaksinen, N.K., Nurmi-Luthje, I.S., Kataja, J.M., Kroger, H.P.J., Luthje, P.M.J., 2018. Cycling injuries and alcohol. Injury 49 (5), 945–952.

Baumann, F., 2019. Basel testet velofreundliche Schienen. Velojournal.

Cameron, I.C., Harris, N.J., Kehoe, N.J., 2001. Tram-related injuries in sheffield. Injury 32 (4), 275–277.

Castanier, C., Paran, F., Delhomme, P., 2012. Risk of crashing with a tram: perceptions of pedestrians, cyclists, and motorists. Transp. Res. Part F Traffic Psychol. Behav. 15 (4), 387–394.

Confederation, S., 2019. Verkehrsregelnverordnung vom 13. November 1962 (vrv). Bern.

Deunk, J., Harmsen, A.M., Schonhuth, C.P., Bloemers, F.W., 2014. Injuries due to wedging of bicycle wheels in on-road tram tracks. Arch. Trauma Res. 3 (4), e23083.

Feng, C., Wang, H., Lu, N., Tu, X.M., 2013. Log transformation: application and interpretation in biomedical research. Stat. Med. 32 (2), 230–239.

Hertach, P., Uhr, A., Niemann, S., Cavegn, M., 2018. Characteristics of single-vehicle crashes with e-bikes in Switzerland. Accid. Anal. Prev. 117, 232–238.

Maempel, J.F., Mackenzie, S.P., Stirling, P.H.C., Mccann, C., Oliver, C.W., White, T.O., 2018. Tram system related cycling injuries. Arch. Orthop. Trauma Surg. 138 (5), 643–650.

Mitra, B., Al Jubair, J., Cameron, P.A., Gabbe, B.J., 2010. Tram-related trauma in melbourne, victoria. Emerg. Med. Australas. 22 (4), 337–342.

Naznin, F., Currie, G., Logan, D., 2016. Exploring the impacts of factors contributing to tram-involved serious injury crashes on melbourne tram routes. Accid. Anal. Prev. 94, 238–244.

Palmer, A.J., Si, L., Gordon, J.M., Saul, T., Curry, B.A., Otahal, P., Hitchens, P.L., 2014. Accident rates amongst regular bicycle riders in tasmania, australia. Accid. Anal. Prev. 72, 376–381.

Papoutsi, S., Martinolli, L., Braun, C.T., Exadaktylos, A.K., 2014. E-bike injuries: experience from an urban emergency department-a retrospective study from switzerland. Emerg. Med. Int. 2014, 850236.

Rutschmann, O.T., Hugli, O.W., Marti, C., Grosgurin, O., Geissbuhler, A., Kossovsky, M., Simon, J., Sarasin, F.P., 2018. Reliability of the revised swiss emergency triage scale: a computer simulation study. Eur. J. Emerg. Med. 25 (4), 264–269.

Sanford, T., Mcculloch, C.E., Callcut, R.A., Carroll, P.R., Breyer, B.N., 2015. Bicycle trauma injuries and hospital admissions in the united states, 1998-2013. JAMA 314 (9), 947–949.

Schweizer Radio und Fernsehen (SRF), 2019. Mehr Sicherheit für Velofahrer - Basel testet neues Tramgleis mit Gummifüllung. SRF1: Regionaljournal Basel.

Shinar, D., Valero-Mora, P., Van Strijp-Houtenbos, M., Haworth, N., Schramm, A., De Bruyne, G., Cavallo, V., Chliaoutakis, J., Dias, J., Ferraro, O.E., Fyhri, A., Sajatovic, A.H., Kuklane, K., Ledesma, R., Mascarell, O., Morandi, A., Muser, M., Otte, D., Papadakaki, M., Sanmartin, J., Dulf, D., Saplioglu, M., Tzamalouka, G., 2018. Under-reporting bicycle accidents to police in the cost tu1101 international survey: cross-country comparisons and associated factors. Accid. Anal. Prev. 110, 177–186.

Swiss Confederation, 2018. Federal Office of Public Health. Tarmed 1.09, Bern.

Swiss Confederation, 2019a. Federal Roads Office. Strassen und verkehr 2019.

Swiss Confederation, 2019b. Federal Roads Office. Unfallstatistik strassenverkehr, pp. 2014–2018.

Swiss Council for Accident Prevention, 2016. Sinus-Report 2016: Sicherheitsniveau und Unfallgeschehen im Strassenverkehr 2015. Bern. Swiss Council for Accident Prevention.

Teschke, K., Dennis, J., Reynolds, C.C., Winters, M., Harris, M.A., 2016. Bicycling crashes on streetcar (tram) or train tracks: mixed methods to identify prevention measures. BMC Public Health 16, 617.

Van Laarhoven, J., Hietbrink, F., Ferree, S., Gunning, A.C., Houwert, R.M., Verleisdonk, E.M.M., Leenen, L.P.H., 2019. Associated thoracic injury in patients with a clavicle fracture: a retrospective analysis of 1461 polytrauma patients. Eur. J. Trauma Emerg. Surg. 45 (1), 59–63.

Vandenbulcke, G., Thomas, I., Int Panis, L., 2014. Predicting cycling accident risk in brussels: a spatial case-control approach. Accid. Anal. Prev. 62, 341–357.

Vereinigung Der Schweizer Veloimporteure, 2017. Velo-bestand in der schweiz.